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BY

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EPIDEMIC PLANT DISEASES.

By F. T. Brooks.

All of us are familiar with disease in an epidemic form as regards illness to which human beings are liable. The widespread occurrence of influenza a few years ago need only be recalled to indicate the chief characters of an epidemic. At that time, many people simultaneously became ill with influenza, which spread with great rapidity from person to person. Thus the principal features of an epidemic are the large numbers of individuals in a population affected by the disease at one and the same time, and the amazing speed with which the malady spreads from the centres where it first occurs.

Plants of economic importance, in which large numbers of individuals of the same kind are usually densely aggregated, are also liable to diseases of an epidemic nature. As in human diseases, plant maladies are frequently caused by parasitic organisms, and epidemic diseases are almost invariably of a parasitic nature; but whereas in animal diseases, these parasites are usually either bacteria or protozoa, the organisms which are the chief source of trouble to plants are of a fungoid nature. Fungoid diseases of animals are known, but most are comparatively infrequent and relatively unimportant. The reasons for this difference in character of plant and animal parasites are by no means clear, but it may be pointed out that bacteria usually thrive best in a slightly alkaline medium that is well provided with complex nitrogenous compounds, and kept more or less constantly at a lukewarm temperature. Blood is such a medium. Fungi, however, are not so exacting in their requirements; they can exist with smaller and simpler supplies of nitrogen especially if carbohydrates are abundant; they flourish over a wider range of temperature, and usually prefer a medium which is slightly acid. Needs of this kind are provided better by plant than by animal tissues. The intercellular spaces with which plant tissues abound are more readily permeated by fungal hyphae than by bacteria.

Not all diseases of plants are of an epidemic nature. Some are sporadic, *i.e.* occur only here and there and not universally over a wide area. Through neglect, however, a disease which is usually sporadic, may assume an epidemic character. Thus silver-leaf disease of fruit trees is usually sporadic in a plum plantation upon first appearance, but if neglected so that the causative fungus, *Stereum purpureum*, fructifies upon the dead branches, the disease may become so prevalent as to be epidemic. With wound parasites there must clearly be widespread opportunity

for infection (*e.g.* exposure) as well as an abundant supply of spores in order for disease to appear in epidemic form.

Epidemic diseases are essentially dependent upon two sets of factors for their development, namely, a condition of the host favourable to invasion by the parasite, and an environment of such a kind as to allow of the rapid dissemination of the spores and germination of these upon the surface of the host; these two sets of factors are intimately related to each other, for conditions detrimental to the growth of the host are often favourable to the development of the parasite. As regards the host being in a state of susceptibility to attack, it is a commonplace that individuals, whether of animal or of plant populations, vary greatly in their liability to certain diseases. It is also well known, that even the most robust individual may become so weakened as to become susceptible to diseases from which normally he is free. Plants of economic importance, most of which have been in cultivation for long ages, exist in the form of numerous varieties which shew marked differences in their susceptibility to disease. Some varieties of wheat are markedly resistant to yellow rust caused by *Puccinia glumarum*, while others are very susceptible; again in potatoes, some forms are badly attacked by the blight fungus and others are scarcely troubled by it. But often even the healthiest forms of cultivated plants may have their vitality so weakened under some conditions as to become a prey to a parasite which usually cannot thrive on it. In India for instance Einkorn wheat, which is noted for its extreme resistance to rust attacks throughout the world, becomes badly attacked by black rust (*Puccinia graminis*) during abnormally hot weather in the Ganges Valley. Climatic conditions in this case doubtless so reduce the vitality of the host plant as to render it susceptible to the parasite.

Granted, however, that the host plant is in a susceptible condition for attack, epidemic disease will not follow unless the germs of the parasite are available in abundance and unless environmental conditions favour their rapid dissemination and germination upon the tissues of the host. In fact it is not too much to say that weather conditions are usually all important in determining whether disease appears in an epidemic form or not. This accounts for differences in incidence of such plant diseases in successive years. The prevalence of one of the commonest epidemic diseases, potato blight, is chiefly determined by weather conditions. In a wet summer great damage may be done by the vigorous spread of this fungus, and so rapid is the onslaught of the parasite under suitable weather conditions that potato fields sometimes become black in a day or two. In a moderately dry summer, potato blight, though usually present

to a slight extent, is of negligible importance. Under these conditions the spores of the fungus are produced in much smaller numbers and the majority of them, even if they alight on potato leaves, are unable to germinate and cause infection on account of lack of moisture. Correlated with a heavier rainfall, potato blight is generally more severe in the west of England than in the east.

If climatic conditions are such as to prevent entirely or almost entirely for a season the occurrence of a disease which is usually epidemic, there may elapse an interval of years before the disease again assumes serious proportions. The dry summer of 1921 prevented almost entirely the appearance of potato blight, which has been uncommon in most parts during 1922 and 1923, notwithstanding weather conditions apparently favourable to it. The reason for this may be that the sources of infection were largely destroyed by the heat and drought of 1921 and that there is a necessary lag until the sources of infection are sufficiently replenished.

In temperate regions epidemic plant diseases are often checked by the oncoming of winter, during which most of these parasites are not present in an infectious condition. Mildews which are propagated in an epidemic manner during the summer by spores of a delicate nature, usually form another type of spore towards the end of the growing season, which is enclosed in an impervious case that remains sealed until the following spring. At the same time the young stems and leaves which are the parts chiefly liable to infection by such fungi either do not exist during the dormant season or have become greatly modified in structure. In the tropics, however, vegetation and weather conditions are both often practically uniform throughout the year, the temperature and rainfall varying but little in successive months. In such a climate there is no close season for fungal parasites, and epidemic diseases are greatly to be feared.

Disease may affect the subterranean parts of plants as well as the stems and leaves, and some of the most serious plant diseases and the most difficult to control are of this nature. In recent years much has been heard of wart disease of potatoes (*Synchytrium endobioticum*) in this country. This parasite invariably causes infection through the soil, in which the resting spores may retain their vitality for many years. A disease of this kind can only be epidemic when the causative parasite is generally distributed throughout the soil, for there is no means of active dissemination by wind currents. There are other ways in which root parasites may become so prevalent as to cause disease more or less of an epidemic nature. Thus if a forest or woodland be cut down and replanted with trees there are several

fungi, which, living at first on the decaying stumps as saprophytes, give rise to mycelial strands that, on passing out into the soil, invade the roots of the newly planted trees and kill them. In the early days of the rubber plantation industry in the Eastern tropics fungi of this kind were a great menace. Here also there was universality of opportunity for infection. In consequence of this danger it is now customary to remove the jungle stumps immediately after the establishment of the plantation, so that no opportunity is afforded for the development of this insidious form of disease.

The sources of infection of epidemic plant diseases are sometimes rather mysterious, and much further work is required in order to elucidate them. Many investigations have been made upon the means of over wintering of *Phytophthora infestans* and still there is obscurity about it. Recently it has been shown that the mycelium of this fungus possesses a limited power at any rate of saprophytic development in the soil and it may be that this is one of the ways in which the fungus survives under natural conditions, especially in such warm areas as the Penzance district and the Isle of Wight. It may be that the fungus is really endemic in such centres in a manner somewhat similar to the continued occurrence of cholera in certain districts in India in years when the disease is not epidemic.

The balance between host, parasite and environment in the causation of epidemic disease is usually of a delicate nature. A slight change in environmental conditions which may favour the host or alternatively injure the parasite may be quite sufficient to prevent the establishment of an epidemic. Thus *Puccinia glumarum* is commonly present in epidemic form on wheat in this country because the temperatures of the winter are usually insufficiently low to kill the uredospores of this fungus. *Puccinia graminis*, on the other hand, is a comparatively rare fungus here (except on cereals in immediate association with barberry bushes) because its uredospores cannot survive the winter temperatures which are harmless to *Puccinia glumarum*.

There is some evidence, perhaps of a not very critical nature, that the parasite itself may be more virulent at certain times than at others. There is a parallel to this in certain human diseases. For instance, during the last few years, there have been successive waves of influenza some of which were much more virulent than others. This was probably due to variations in virulence of the bacteria causing the disease, although it may be argued that this phenomenon resulted from a special degree of susceptibility on the part of mankind at the time of most serious attack. With plant parasites it is often found that, upon introduction into a new country, they spread with great rapidity

during the first few years until a climax of intensity is reached, after which their attack is less serious. Thus potato blight was introduced into Europe during the early part of the nineteenth century and rapidly spread so that in 1840 it was responsible for a complete failure of the potato crop in Ireland, thereby causing a serious famine; it is doubtful whether this fungus has ever been so virulent since. Another illustration may be taken from a disease which has been introduced into this country in recent years. About 1900 American gooseberry mildew became accidentally established in the British Isles, and immediately began to spread rapidly, so that in a few years all fruit areas where gooseberries were grown on a large scale were attacked by the disease. After some years, however, this parasite became less prevalent, and it may be that its period of maximum virulence has passed, although there has been a considerable recrudescence of the disease during 1922 and 1923.

The example of American gooseberry mildew is an illustration of the danger of the introduction of a parasite to a country where it is not native. Sometimes the climatic and other conditions of the new country are unfavourable to the parasite, but frequently it is otherwise, when there is grave risk of the establishment of disease in epidemic form. There are two destructive tree diseases in the United States which illustrate this principle. One of these is a fungus, known as *Endothia parasitica* which, native on certain species of chestnut trees in China, has in some unknown manner been introduced into the eastern parts of the United States, where it has caused immense damage to indigenous chestnut trees. The spores of this fungus germinate on slightly wounded parts of the branches and trunks of these trees, causing infection of the bark, which is rapidly killed. This fungus, at first only sporadic, has spread over large areas, notwithstanding the costly efforts that have been made to check it by felling wide belts of trees between diseased and healthy areas.

Another disease which has aroused consternation in the United States is the blister rust of five-needled pines, including the valuable Weymouth pine, *Pinus strobus*. It is known exactly how this disease was introduced into America, and the story is not uninteresting. The Weymouth pine is native to the United States, and being a valuable timber tree, has been used for forestry purposes in Central Europe. Nurseries of this tree were established in European countries where there are other closely allied pines which are attacked by the rust fungus, *Cronartium ribicola*, the disease affecting chiefly the bark of the trees. Upon the introduction of the Weymouth pine to these countries, it also was attacked by this fungus. For some extraordinary reason American foresters sent to Europe for nursery stock of

the Weymouth pine, instead of relying on their own resources. In those days there was no adequate system of plant disease inspection at the ports, and it was subsequently found that this European nursery stock introduced with it the deadly blister rust fungus which began to spread to the indigenous Weymouth pines before measures were taken to combat it. This disease is now one of the most serious that American foresters have to contend with, and its introduction shews the folly of allowing cultivated plants to be distributed throughout civilised countries without safeguards to prevent the transmission of disease. The blister rust of the Weymouth pine is unfortunately common in this country, and is the chief reason why this tree is not used more extensively for afforestation. Epidemic disease on these pines is here dependent upon the presence of an alternate host, *Ribes* spp., because the fungus cannot propagate itself directly from pine to pine. On the other hand the presence of pines (apart from an initial source of infection) is not necessary for the continuation of an epidemic on currant bushes.

Again, when a new plant is introduced into a country, a parasite often attacks it violently although the pest has only been found hitherto sporadically upon related indigenous plants. Coffee was introduced into Ceylon as a plantation crop about 1870, and an important industry sprang up in connection with it. Soon, however, it began to be attacked by a fungus disease (*Hemileia vastatrix*), which up to that time had only occurred to a slight extent upon jungle plants closely related botanically to coffee. With large numbers of plantations in close proximity to each other, the disease spread rapidly and became so uncontrollable that coffee-growing in the island became unprofitable. Heavy losses were incurred, and a few years after the commencement of the epidemic, coffee ceased to be grown on a commercial scale in that part of the tropics. That is an illustration of the danger of disease breaking out in epidemic form upon a newly introduced economic plant, the disease itself, although indigenous, being of negligible importance until the appearance of the specially susceptible plant.

Epidemic diseases of plants are disseminated in various ways. Most of the parasites produce spores which can retain their vitality for considerable periods unless exposed to extremes of temperature, insolation or desiccation. Many of these diseases, therefore, can be distributed over relatively wide areas by means of wind currents. With such a disease as potato blight this is undoubtedly the chief means by which the fungus is spread in an epidemic condition. Upon first development of the fungus in an active or sporing state in any season, the disease in its initial

stages is present only on a few plants in the crop. Spores are produced on these plants and are then distributed by wind so that other plants in the vicinity become infected. The same considerations apply to mildews and rust fungi. The power of wind, however, to disseminate fungoid diseases over immense areas, has undoubtedly been exaggerated. It used to be thought that disease could be spread in this manner from one country to another over wide tracts of sea, but this has been shown to be untrue. Delicate fungus spores which have been in the air a long time have probably been exposed to many vicissitudes of temperature, insolation, and desiccation. These changes greatly impair their vitality and by the time they reach a plant susceptible to infection, most of them are dead. It has been demonstrated for instance that bacterial germs are rapidly killed by exposure to strong light, and doubtless the same appplies to many fungus spores. Furthermore, spores being light bodies are to a great extent carried by convection currents to the upper atmosphere, where conditions are of a more extreme nature, and from which many of these germs will not fall in a living condition.

The limited power of wind currents to disseminate fungoid diseases is well illustrated by certain heteroecious rust parasites. One of these (*Puccinia Pruni-spinosae*) alternates between certain species of anemone and plum trees, in the former of which the fungus lives indefinitely, producing spores each spring. These spores infect plum leaves, but it is only the trees in the immediate vicinity of the infected anemones, especially in the direction of the prevailing wind, that first become attacked. The spores produced on the anemone seem only to be able to infect the alternate host within the range of about a mile or so, and it is not until secondary spores are formed on the plum leaves that the fungus spreads over wider areas. These secondary spores are formed within about ten days of infection, and the fungus is propagated by these during the summer in ever-widening circles.

Nowadays emphasis is laid upon the need for contact in the dissemination of many parasitic organisms. By maintaining contact, is meant bringing the parasite into the immediate vicinity of a healthy and susceptible host by means of some living or mechanical agency. This has long been recognised in human diseases, for, in many of these, individuals only become attacked by coming into close association with others already affected, notwithstanding the fact that the germs of many of these diseases must be commonly present in the air. The inability of the germs casually present in the air to cause infection is due partly to the fact that their vitality is rapidly destroyed by exposure to bright sunlight and partly to the germs being present in quantity less than the minimum requisite to cause

infection. In connection with the point last mentioned, it is a well-known axiom in medical science that the danger of infection increases with the magnitude of the dose of the disease, so to speak, to which one is exposed; there is no doubt, for instance, that even the healthiest man would succumb to tuberculosis if he inhaled an atmosphere saturated with the tubercle bacillus. With plant diseases the same principles are only just beginning to be recognised. The means by which the germs of these diseases are brought into contact with their hosts are often different from those of animal diseases, but they are none the less sure. It is now known that many infectious plant diseases are chiefly spread by insect agency, and occasionally by birds. There is a widespread group of plant diseases of great economic importance, known as mosaic diseases, which are characterised first by a mottling of the leaves with yellow spots and then by general degeneration. No organisms have yet been isolated which can be considered the cause of these diseases, but if the sap of an affected plant is inserted into a healthy one, the latter soon becomes diseased. Such diseases and others of a similar nature are known as viruses. They are of common occurrence in animals and are often supposed to be due to organisms of ultra-microscopic size. Foot and mouth disease in animals and the mosaic diseases of tobacco and potatoes are maladies of this nature. Mosaic disease of tobacco is one of the chief factors limiting the growth of the finest kinds of tobacco in those regions of the tropics, such as Sumatra, otherwise favourable for their growth. It has been shown recently that these mosaic diseases are largely spread by means of insects, especially by aphides, which, having visited diseased plants, puncture healthy ones, and thereby insert the virus. Apart from mosaic diseases, insects play an important rôle in the dissemination of plant maladies caused by known parasitic organisms, whether bacteria or fungi. The insect in sucking or biting the tissues of a diseased plant inevitably comes in contact with the germs of the parasite, some of which adhere while it passes to another plant, which may thus become infected. In fact, so intimate is the incidence of certain insect and fungus pests, that widespread opinions prevail amongst cultivators that fungi inevitably follow particular insects. One of the commonest diseases of apple trees is "canker," caused by the fungus, *Nectria galligena*, which sometimes follows in the wake of woolly aphis, one of the most serious insect pests of apple trees. This sequence is probably assisted in two ways, first by the insect carrying the spores of the fungus entangled in its woolly appendages, and secondly because the insect punctures the bark, thereby creating wounds by which the fungus can invade the branches. Again, in the rubber plan-

tations of Malaya one of the diseases of rubber trees is an affection of the bark which is brought about frequently by the combined action of an insect and a fungus. The insect is a boring beetle which usually attacks only dead wood, but which under certain circumstances invades the bark of living rubber trees, especially if this has been exposed to injury. In the dead wood inhabited by these borers the fungus *Ustulina zonata* is often found growing as a saprophyte, and as the boring insects pass from the dead wood to the living rubber trees they carry with them the fungus which, upon being thus established in the tissues of the rubber trees, spreads rapidly and acts as a destructive parasite. Such instances could be multiplied many times.

Not only do animals of a lower order play an important part in the dissemination of plant diseases, but man himself must plead guilty to this offence. Civilisation is responsible for certain evils, not the least of which is the scattering broadcast over the world of serious plant pests by the hand of man. This has only recently come to be recognised, unfortunately too late to prevent the introduction into new countries of some pests which cause great havoc. As often happens, the stable door has been locked after the horse has gone, but many countries have now established a system of plant import inspection which will prevent the introduction of new troubles of this kind. In the United States this control of plant imports is now so rigorous that certain classes of plants are entirely excluded from entry into the country. A few illustrations may be given of some of the ways in which the agency of man may be traced in the distribution of fungus pests. Less than twenty years ago, wart disease of potatoes was known to exist only at a few places in England and Scotland, but since then it has spread to some extent practically all over these countries and has reached America also. Some of the districts infected with this disease are renowned for the quality of their "seed" potatoes, which, in consequence, get distributed far and wide. During the war, when every effort had to be made to grow the maximum quantity of potatoes, "seed" tubers were distributed from one part of the country to another on a much bigger scale than ever before. There is no doubt that in this process wart disease was distributed at the same time. No one of course could think of using "seed" tubers bearing the warty outgrowths characteristic of this disease, but tubers apparently healthy, may bear the resting spores of this fungus in particles of soil adhering to the tubers. Certain varieties of potatoes are entirely immune to this disease. Notwithstanding their own immunity, these varieties may be the means of carrying the disease to healthy gardens, for the

spores adhering to the surface become detached into the soil and are there ready to infect any susceptible variety that may be planted in following years. During the war it was impossible to ensure that no seed potatoes were taken from infected land, and hence the disease is now present to a certain extent at any rate in practically every county in England, whereas only a few counties were affected in the year before the war. There is no doubt that the fungus was introduced into the United States some years ago by the importation of seed potatoes. In another class of disease, such as a surface mildew, of which American gooseberry mildew is a convenient example, two types of spores are produced; one of these propagates the fungus rapidly during active growth in the summer; the other is enclosed in an impervious covering and serves to tide the fungus over adverse winter conditions, these spores germinating in the spring upon release from their protective coats. Both types of spores may be distributed by mechanical means in the following manner. The winter "spores"—as one type may be called—adhere to the twigs of the gooseberry bushes and may be inadvertently carried in this way from nurseries to commercial and private gardens. It is customary before gooseberry bushes are despatched from a nursery where mildew has been present, to cut back the extremities of the shoots, but this precaution does not entirely ensure against the resting "spores" being distributed with the nursery stock, because these may fall on to the bud scales or into cracks in the bark. The summer spores, which are scattered to some extent by wind currents, may be distributed over wider areas by other agencies. The baskets in which the gooseberries are sent to market have been one such means: it is impossible to exclude all diseased fruit in packing, the spores from which may be carried with the basket to a new destination, for the empty baskets are not always returned to the place from which they were sent. Spores which adhere to these baskets get blown on to healthy bushes and infect them. During the period when American gooseberry mildew was spreading rapidly in this country it was quite common to find that the first bushes in a plantation to become diseased were those in the neighbourhood of the packing sheds, *i.e.* in the immediate vicinity of the place where the baskets returned from the market were stored. Spores of such diseases may also be carried directly by human agency. Persons walking amongst diseased plants may carry away with them spores adhering to their clothes. Upon going to another garden, these spores may fall from their clothes and infect healthy plants.

The economic losses caused by fungal diseases in general and by those of an epidemic nature in particular are collectively

enormous. Probably many millions of pounds are lost every year by the attacks of parasitic fungi upon food plants. It is by no means unknown for a disease of epidemic character to wipe out the cultivation of a certain product in an entire country, but the toll levied is usually of a more insidious kind. For instance, even in the best wheat-growing countries, the losses of crop due to attacks of rust fungi are computed to be rarely less than 10 per cent., and are often more, while in certain parts of Canada, Australia and Africa, the loss of crop from this cause may be nearly complete. With wound parasites, the losses may be equally serious if the diseases caused by them are neglected.